Short-term High Temperature Effects on Stomatal Behaviors of Rice Plants. II. Occurring at the Grain-filling Stage[1]

Chwen-Ming Yang[2] and James L. Heilman[3]

Abstract : Effects of a short period (8 days) of high temperature (35 C), relative to 25 C, occurring at the grain-filling stage (from the 8th to 15th day from heading) on stomatal behaviors of rice plants (*Oryza sativa* L.) were studied under controlled environment. The results showed that high temperature stimulated the opening of stomata yet preserved the diurnal pattern of stomatal variations during the course of treatment. A near parallel fashion between the curves of temperature treatments was observed and the difference was most distinguished in the middle part of photoperiod, After treatments, heat-treated plants had lower stomatal conductances until harvest. This phenomenon may affect carbon balance and grain-filling processes and hence yield production.

Key words : high temperature effect, stomatal behavior, conductance, rice, *oryza sativa* L., grain-filling stage.

Introduction

Many features of leaf structure and physilogical functions alter as leaf ages. Stomatal conductance also varies with plant age and leaf position and the intricated effects of envirinmental variables (Jones, 1979; Turner and Heichel, 1977;Yang and Heilman, 1990b). Yang and Heilman (1990b) further found that the diurnal patterns of stomatal behavior of rice were shown in the seasonal fashion. This may be the result of an accumulated wax barrier and polysaccharide substances in guard cells and leaf layers as the plant ages (Palevitz, 1981; Willmer, 1983).

In the previous report (Yang and Heilman, 1990a), it was identified that stomatal conductances of rice plants were elevated by high temperature during treatment period in the vegetative stage. Temperature effects may extend up to Leaf 13 stage, or 45 days after treatment.

There is still the need, however, for detailed observations of diurnal changes of stomatal movemnents upon heat stress in rice during the grain-filling period, information of which

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2. Agronomist, Department of Agrononmy, TARI, Wufeng, Taichung, Taiwan 41301, ROC.
3. Associate professor, Department of Soil & Crop Sciences, Texas A&M University, College station, Texas 77843, USA.

is required to clarify the role of stomata in carbon balance and yield production. Also, little in known about short period high temperature occurring at the grain-filling stage to the long -term effect of stomatal movements. Such information can provide some insights into effects of short period heat stress on stomatal behaviors in the life span of rice plants, which is often the case in the field.

Materials and Methods

Rice plants Lemont (Bollich et al., 1983, 1984) were grown in controlled-environment growth chamber until the appropriate stage before temperature treatments. The growing procedures and the growth conditions of growth chamber and asssimilation cabinet were described in details in the previous report (Yang and Heilman, 1990a). When reaching the R-1 stage, plants were moved to an assimilation cabinet for 8-day temperature treatments (day/night temperatures 35 C/35 C and 25 C/25 C), and then returned back to the growth chamber and grown to maturity.

Heading stage is defined as from the first day to the 7th day from heading (one week); the R-1 stage is the time period from the 8th to the 14th day from heading, and so on. Stomatal (leaf) diffusive resistance was measured in the middle portion of the uppermost fully expanded primary leaf by a porometer (MK3, Delta-T Devices, England). For diurnal data, the first measurement was taken at 0800 h, the onest of photoperiod, and the measurements were contimued every two hours until 2000·h, the end of daytime hours. Stomatal conductance, the inverse of stomatal resistance, was used throughout this study, The mean values and standard deviations were taken from the averages of each group; at least four groups for each mean value.

Results and Discussion

Despite the heat shock, the diurnal patterns of stomatal conductance were identified in both temperature treatments as shown in Fig. 1. A parallel fashion for stomatal conductances was observed between the curves during most of the daytime hours. High temperature produced higher stomatal conductances yet preserved diurnal variations. Such behaviors are similar to the results in the vegetative stage as previously reported (Yang and Heilman, 1990a). Yang and Heilman (1990b) and others (Martin and Meidner, 1971;Martin et al., 1983) demonstrated the viewpoint that stomatal movement is under endogenous controls, expressed in a circadian rhythm of opening and closing. In this series of studies, it further showed that stomatal opening is stimulated at 35 C yet the diurnal pattern of stomatal variations is preserved. both in the vegetative and the reproductive stages.

When transferred back to the growth chamber with a day/night temperatures of 30 C/20 C, however, stomatal conductances for the 35 C were lower than those of the 25 C treatment until harvested (Fig. 2). The difference between temperature treatments was more discernable at 1400 h (Fig. 3). The results were in contrast to the results reported in the vegetative stage (Yang and Heilman, 1990a). Since old and existing leaves senesced at a greater speed after high temperature treatment, relative to 25 C treatment, it is not surprised that lower conductances were observed in the heat-treated plants. Yang and Heilman

(unpublished data) found that, in the long run, short-term heat stress in the vegetative stage may not affect yield while heat stress during grain-filling may dramatically reduce yield. Differences in physiological mechanisms, such as gas exchange, carbon balance and root functions, and in morphological and reproductive modifications, such as agronomic and yield characteristics, between temperature treatments and between growth stages are therefore should be examined for a full picture.

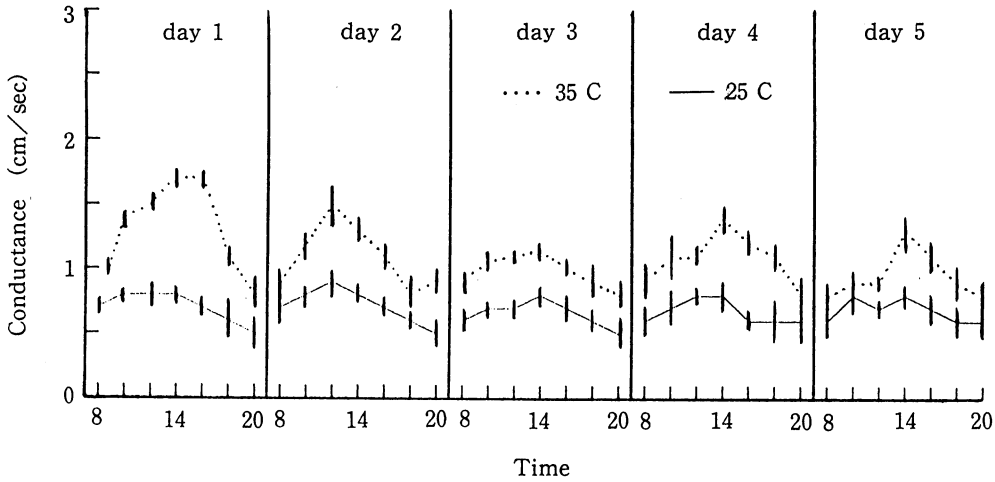

Fig 1. Effects of temperature treatments (35 C and 25 C) at the R-1 stage on the diurnal changes of stomatal conductances of the uppermost fully expanded primary leaf. Stanard deviation is included.

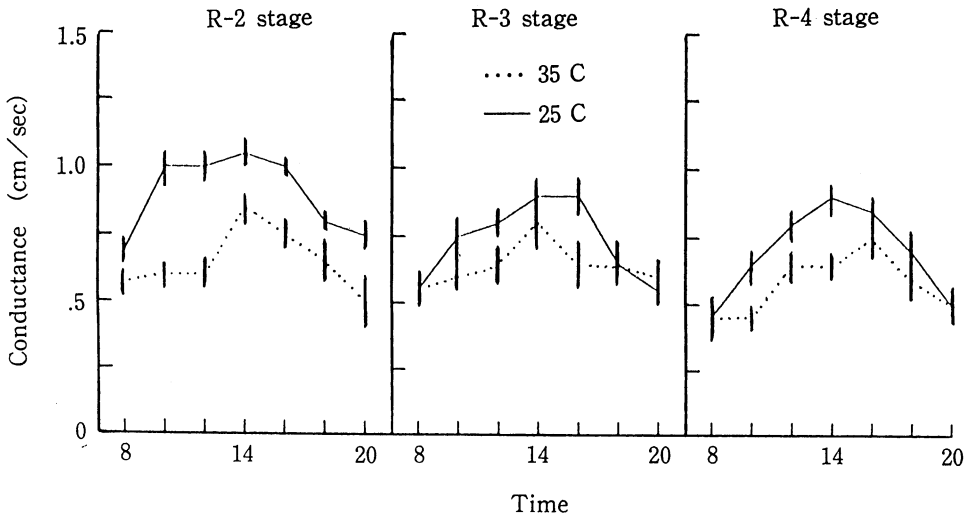

Fig 2. The diurnal changes of stomatal conductances of the uppermost fully expanded primary leaf in the R-2, the, R-3,and the R-4 stages as affected by 8-day temperature treatments imposed at the R-1 stage. Standard deviation is included.

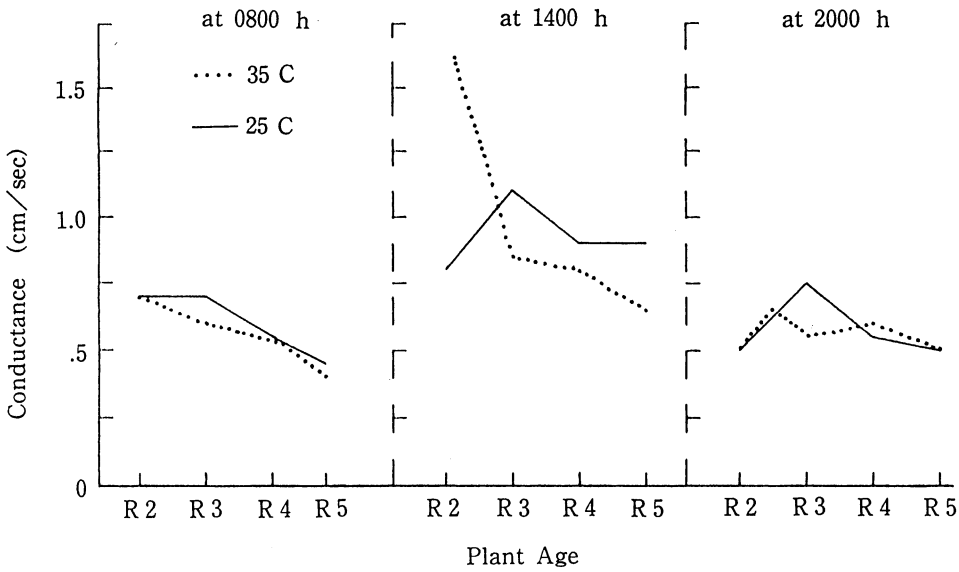

Fig 3. Stomatal conuctances at 0800, 1400, and 2000 h as functions of temperature and plant age.

As a result, stomatal movements of rice plants are sensitive to temperature changes both in the vegetative and the reproductive phases. Theoretically, stomata are important in regulating water vapor and carbon dioxide exhange and, hence, transpiration and photosynthesis. The physilogical importance of their functions, however, is dependent on the balance between conesrving water and conesrving maximal production as well as the interactions between stomata and environmental variables (Jones, 1987).

References

1. Bollich, C.N., B.D. Webb, M.A. Marchetti, J.E. Scott, and J.W. Stansel. 1984. Lemont characteristics and performance. In : The Semidwarf-A New Era In Rice Productin. p. 2—10. The Texas Agri. Exp. Sta., College Station, Texas, USA.
2. Bollich, C.N., B.D. Webb, M.A. Marchetti, and J.E. Scott. 1985. Registration of Lemont rice. Crop Sci. 25: 883—885.
3. Jones, H.G. 1979. Stomatal behavior and breeding for drought tolerance. In : Stress Physiology In Crop Plants. p. 407—428. H. Mussel and R.C. Staples, eds. John Wiley & Sons, New York.
4. Jones, H.G. 1987. Breeding for stomatal characters. In : Stomata Function. p. 431—443. E. Zeiger, G.D. Farquhar, and I.R. Cowan, eds., Stanford Univ. Press, Stanford, California.
5. Matin, E.S. and H. Meidner. 1971. Endogenous stomatal movements in *Tradescantia virginiana*. New Phytol. 70 : 923—928.
6. Martin, E.S., M.E. Donkin, and R.A. Stevens, 1983, Stomata. p. 10—28. Edward Arnold, London.
7. Palevitz, B.A. 1981. The structure and development of stomatal cells. In : Stomatal Physiology. p.1—23. P.G. Jarvis and T.A. Mansfield. eds. Cambridge Univ. Press, Cambridge/London.

8. Turner, N.C. and G.H. Heichel. 1977. Stomatal developmemnt and seasonal changes in diffusive resistance of primary and regrowth foliage of red oak (*Quercus rubra* L.) and red maple (*Acer rebrum* L.). New Phytol. 78: 71—81.
9. Willmer, C.M. 1983. Stomata. p. 6—27. Longman, London.
10. Yang, C-M. and J.L. Heliman. 1990a. Short-term high temperature effects on stomatal behaviors of rice plants. I. Occurring at the vegetative stage. J Agric. Res. China 40:233—242.
11. Yang, C.-M. and J.L. Heilman. 1990b. Diurnal and seasonal stomatal behaviors of rice plants grown in controlled environment. Chinese Agron. J. 1:147—156.

短期高溫處理對水稻氣孔表現之效應
II. 穀粒充實期[1]

楊純明[2] James L. Heilman[3]

摘 要

本試驗在控制環境下，觀測水稻（*Oryza sativa* L.）穀粒充實期間短期高溫處理（35°C，8天）對於氣孔運動之影響，並探究溫度處理後氣孔之表現。結果顯示，高溫提高處理期間之氣孔傳導度，但不影響其每日週期性之行爲，此一溫度處理間（25°C及35°C）之差異呈現平行趨勢，而以光期中段相差最大。短期高溫亦造成處理後氣孔傳導度之降低，直至收穫爲止。該現象對碳素平衡與穀粒充實，乃至產量，產生深遠影響。本試驗同時發現，穀粒充實期間水稻葉片在控制環境下經溫度處理後仍具有氣孔運動。

關鍵詞：高溫處理，氣孔行爲，水稻，*Oryza sativa* L.，穀粒充實期，控制環境

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1. 臺灣省農業試驗所研究報告第 1575 號。
2. 本所農藝系副研究員。臺灣省 臺中縣 霧峰鄉。
3. 美國德州農工大學土壤暨作物系副教授。美國 德州 大學城。